FY04 Luminosity Plan

Presentation to the Board of Overseers

October 3, 2003

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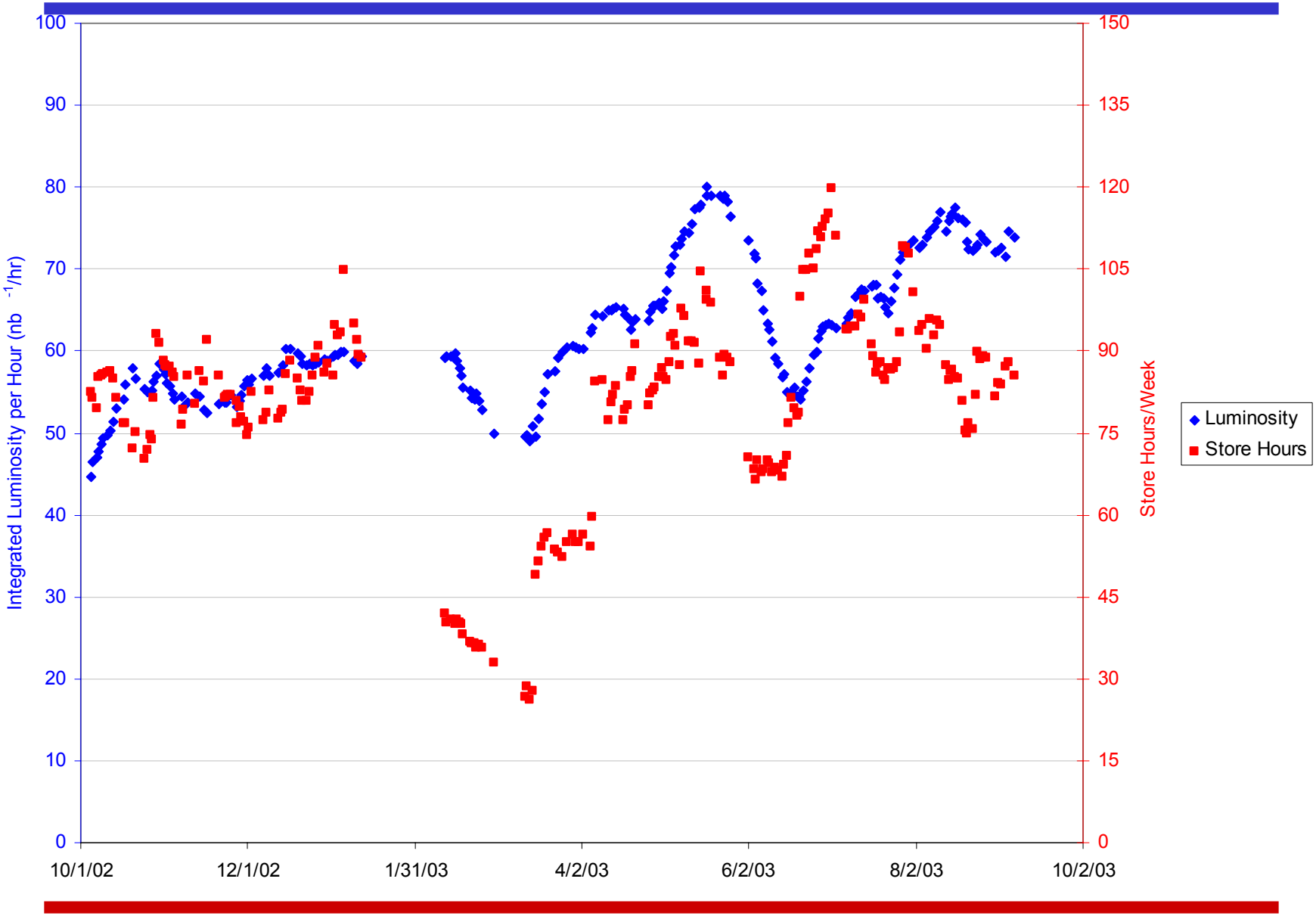
Outline

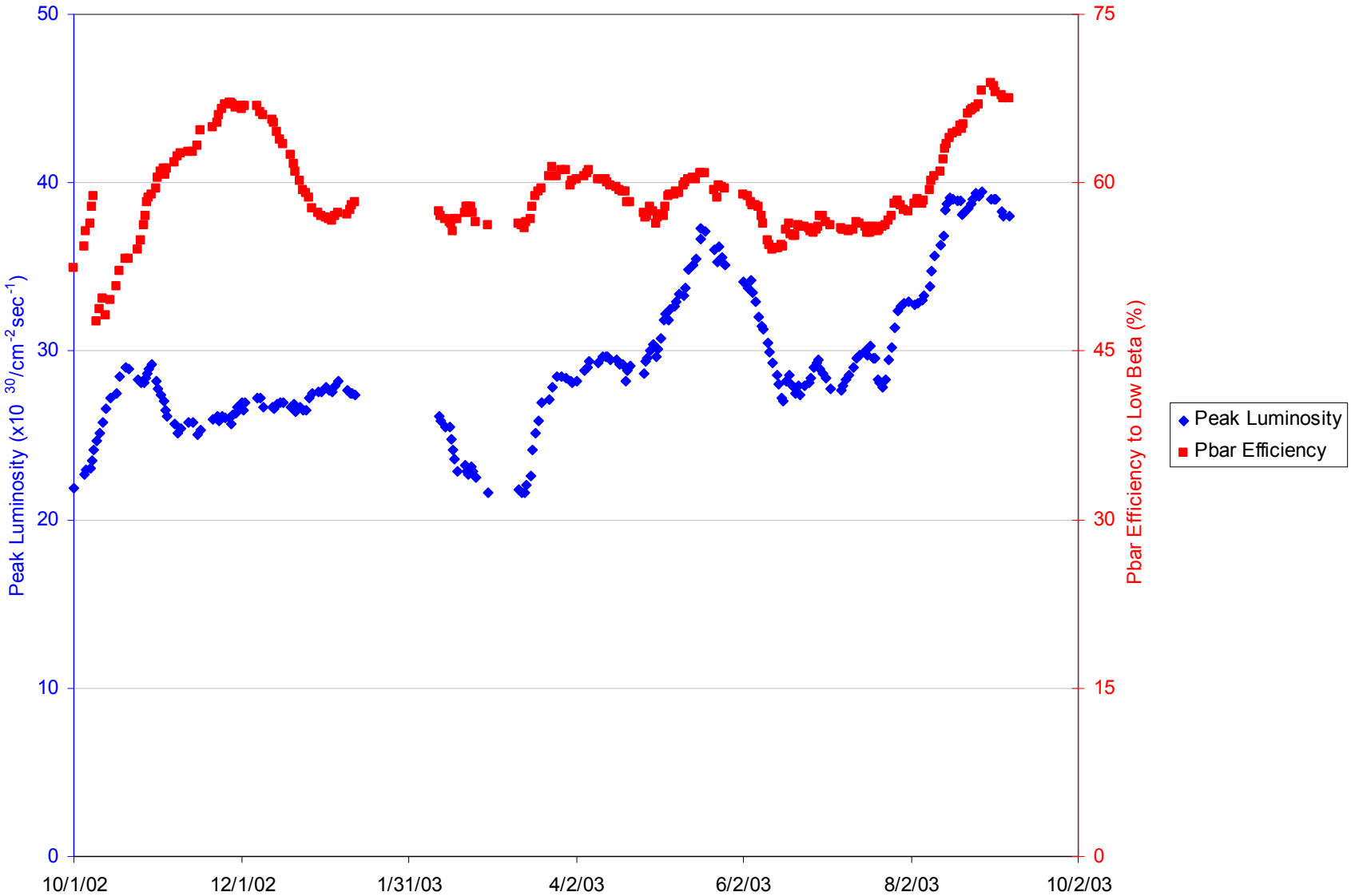
- FY03 Performance
- Accelerator Issues
  - TEV
  - Pbar
  - Main Injector
  - Reliability
- Operations
  - Study Strategy
  - Shot Strategy
- FY04 Luminosity Parameters

FY03 Performance

FY03 Performance



FY03 Performance



FY03 Performance

Parameter	Last Store	Last 10 stores Average	Last 10 stores St. Dev.	Last 50 stores Average	Last 50 stores St. Dev.	
Initial Luminosity (Average)	40.2	37.5	4.6	36.1	6.5	$x10^{30}cm^{-2}sec^{-1}$
Integrated Luminosity per Store (Averaged)	1510.3	1053.0	396.9	1088.9	495.7	nb^{-1}
Luminosity per week (Averaged)	-	5.6	-	6.4	-	pb^{-1}
Store Length	19.9	14.1	5.4	14.9	6.7	Hours
Store Hours per week	-	75.5	-	87.8	-	Hours
Shot Setup Time	2.5	2.2	0.3	2.3	0.6	Hours
Protons per bunch	238.2	237.3	22.6	237.3	18.8	$x10^{9}$
Proton Efficiency to Low Beta	58.0	59.9	3.4	58.3	4.7	%
Antiprotons per bunch	22.6	22.5	3.0	22.2	2.6	$x10^{9}$
Start Stack	118.8	134.6	26.5	144.3	22.1	$x10^{10}$
End Stack	11.8	14.8	5.4	16.5	11.0	$x10^{10}$
Unstacked Pbars	107.0	119.8	24.0	128.2	19.6	$x10^{10}$
Pbar Transfer efficiency to Low Beta	76.0	68.5	6.3	63.3	7.7	%
HourGlass Factor	0.63	0.64	0.01	0.63	0.01	

Accelerator Issues

Run II (without the Recycler) and Run Ib

- Projected - 5.3x ($8.5 \times 10^{31} cm^{-2} sec^{-1}$ / $1.6 \times 10^{31} cm^{-2} sec^{-1}$)
- Delivered – 2.3x ($3.7 \times 10^{31} cm^{-2} sec^{-1}$ / $1.6 \times 10^{31} cm^{-2} sec^{-1}$)
- More Pbars
  - projected - 3.3x
    - More protons on target - 2x ($5 \times 10^{12} / 2.5 \times 10^{12}$)
    - Faster Pbar cycle rate - 1.6x (2.4sec/1.5sec)
  - delivered - 1.9x
    - More protons on target - 1.9x ($4.7 \times 10^{12} / 2.5 \times 10^{12}$)
    - Faster Pbar cycle rate - 1x (2.4sec/2.4sec)
- More Protons
  - projected - 1.17x ($270 \times 10^{9} / 230 \times 10^{9}$)
  - delivered – 1.09x ($250 \times 10^{9} / 230 \times 10^{9}$)
- Shorter Bunch lengths
  - projected form factor - 1.25x (0.37m <- 0.6 m)
  - delivered form factor – 1.07x (0.52m <- 0.6 m)
- Higher Energy
  - projected – 1.11x (1000 GeV/ 900 GeV)
  - delivered – 1.09x (980 GeV/ 900 GeV)

TEVATRON Issues

- Transverse Emittance Dilution at injection
  - Transmission efficiency to low beta
  - Long range Beam Beam effects – big beam sizes
- Chromaticity control
  - Lifetime at 150 GeV
  - Stability – number of protons at low beta
- Helices
  - Transmission efficiency to low beta
  - Long range Beam Beam effects
- Reliability

TEVATRON Transmission Efficiency

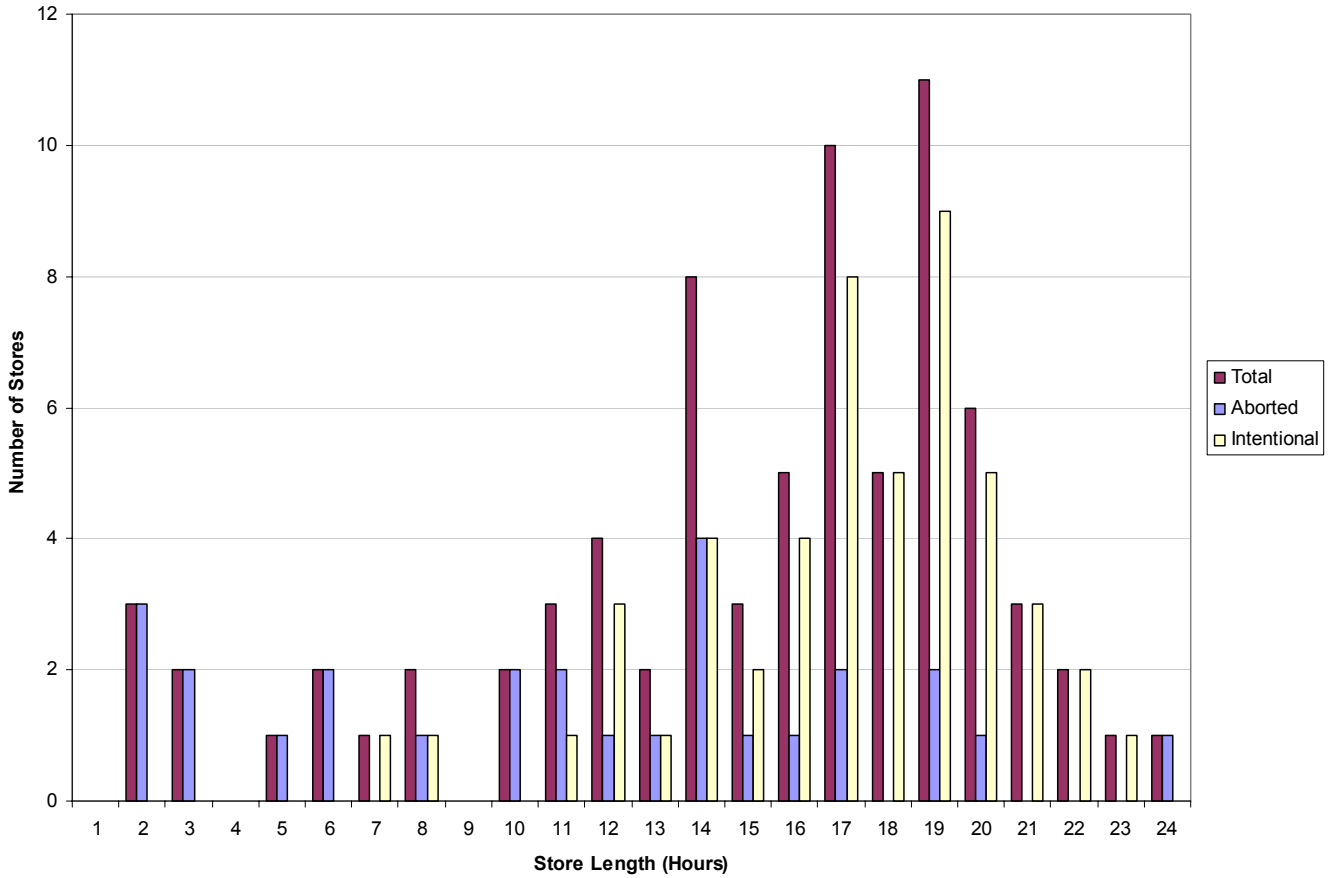
- We made very good progress during the summer of 2003 in increasing the efficiency from 60% to 73% (SBD corrected)
- At first glance, 73% antiproton transmission efficiency from the Accumulator Core to Low Beta seems to be very low.
- However, the 73% transmission efficiency is composed of many stages of transfers each with relatively good efficiency $73\% = (94\%)^5$
- To improve the transfer efficiency to 90%, the average efficiency of each stage of the pbar transfer must increase from 94% to 98%
- Increasing the pbar transfer efficiency from 73% to 90% will increase the luminosity by a factor of 1.23

TEVATRON Projects

- Transverse Emittance Dilution at injection
  - Injection lattice matching for pbars and protons
  - Smart bolt retro-fit to be (this shutdown)
  - New TEVATRON sextupole (borrowed from Pbar)
  - Injection dampers for pbars
- TEVATRON Chromaticity Control
  - Shielding of the F0 Lambertsons
  - Re-wiring of the TEV octupole circuits
- Better TEV Helices
  - Optimized helices at 150 GeV
  - TEV alignment

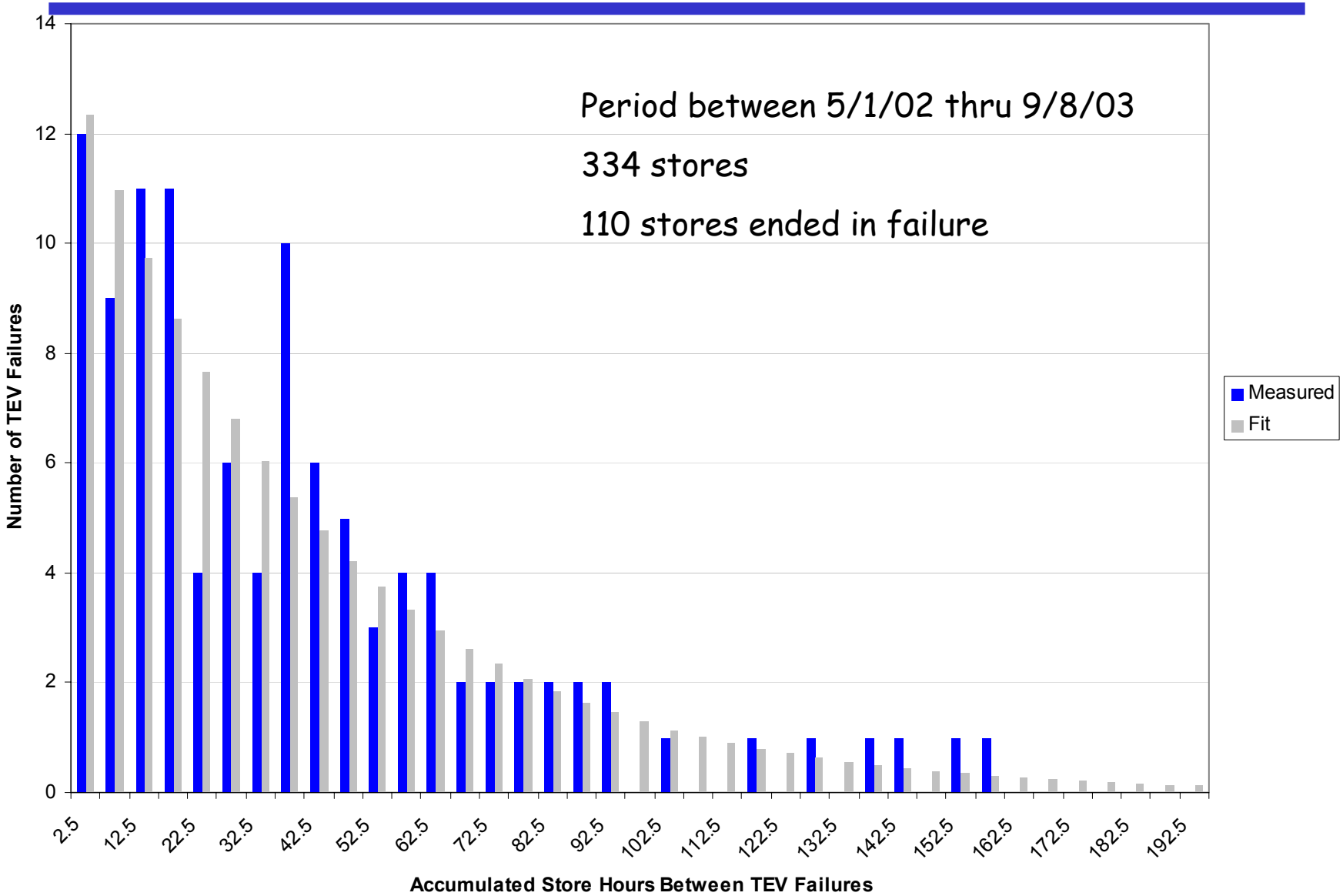
TEVATRON Reliability

- Our highest luminosities were obtained by shooting from large stacks



- These large stacks were obtained by stacking for a long time because the previous store lasted a long time
- Our desire is to run long stores and stack big.
- However, our average store length is limited by equipment failure

TEVATRON Reliability



TEVATRON Reliability

- A TEV failure is independent of the time in the store (exponential distribution)
  - The mean number of store hours between failures is 42 hours
  - 42 hours translates to a TEV reliability of 97.6% per hour
    - The probability that the TEV will remain at up for the next hour is 97.6%
- A TEV Reliability of 97.6% predicts that:
  - 1 out of every 4 stores will end in failure if our target store duration is 12 hours
  - 1 out of every 3 stores will end in failure if our target store duration is 17 hours
- Increasing the reliability by 1% will, on average, require the doubling of the lifetime of TEV components

Pbar Production

- Because our average store length is limited by equipment failure:
  - The only way to increase the luminosity significantly in FY04 is to increase the stacking rate.
  - The Pbar stacking rate is limited between "cooling" cycle time
- Pbar Cooling Cycle Projects
  - Debuncher Momentum Cooling Notch Filter Equalizers
  - New Stacktail BAW filters
  - Improved Stacktail crossover
  - Main Injector Beam loading compensation through the entire acceleration ramp
  - Main Injector Longitudinal Dampers

Luminosity Parameters

Luminosity Parameters			
Phase	FY03	FY04	
Initial Luminosity	37.9	74.9	$x10^{30}cm^{-2}sec^{-1}$
Average Luminosity	20.7	44.4	$x10^{30}cm^{-2}sec^{-1}$
Integrated Luminosity per week	6.4	13.7	pb^{-1}
Integrated Luminosity per store	1.1	2.4	pb^{-1}
Number of stores per week	5.7	5.7	
Average Store Hours per Week	85	85	Hours
Store Length	15	15	Hours
Store Lifetime	11.0	13.0	Hours
HEP Up Time per Week	98	98	Hours
Good Week Ratio	1	1	
Shot Setup Time	2.2	2.2	Hours
	FY03	RED	

TEV Helices

TEVATRON Parameters

TEVATRON Parameters			
Phase	FY03	FY04	
Number of Protons per bunch	250	260	$x10^9$
Number of Pbars per bunch	24.9	37.6	$x10^9$
Proton Emittance	32	29	π-mm-mrad
Pbar Emittance	16	13	π-mm-mrad
σ_{proton}	0.525	0.500	meters
σ_{pbar}	0.525	0.500	meters
BetaIP	40	35	cm
Transfer Eff. To Low Beta	0.73	0.8	
Using SBD Calibration Back Calculated Emittances	FY03	RED	

FO Lambertson

TEV Injection Matching

TEV Injection Coupling

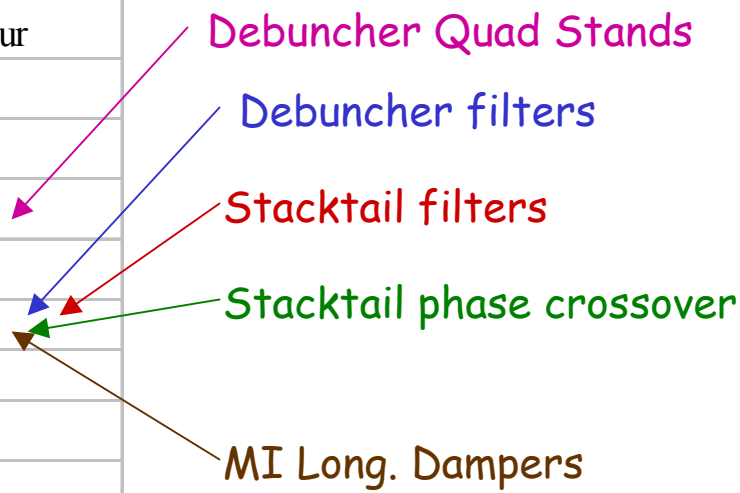
TEV Helices

MI Long. Dampers

TEV Chromaticity control

Antiproton Production Parameters

Antiproton Parameters			
Phase	FY03	FY04	
Zero Stack Stacking Rate	11.3	18.0	$x10^{10}$/hour
Average Stacking Rate	8.2	11.3	$x10^{10}$/hour
Stack Size transferred	122.6	169.1	$x10^{10}$
Stack to Low Beta	89.5	135.3	$x10^{10}$
Pbar Production	15.0	17.0	$x10^{-6}$
Protons on Target	5	5	$x10^{12}$
Pbar cycle time	2.4	1.7	Secs.
Pbar up time fraction	1	1	
Initial Stack Size	15	15	$x10^{10}$
Stack Size at 1/2 Stacking Rate	150	150	$x10^{10}$
	FY03	RED	



Operations

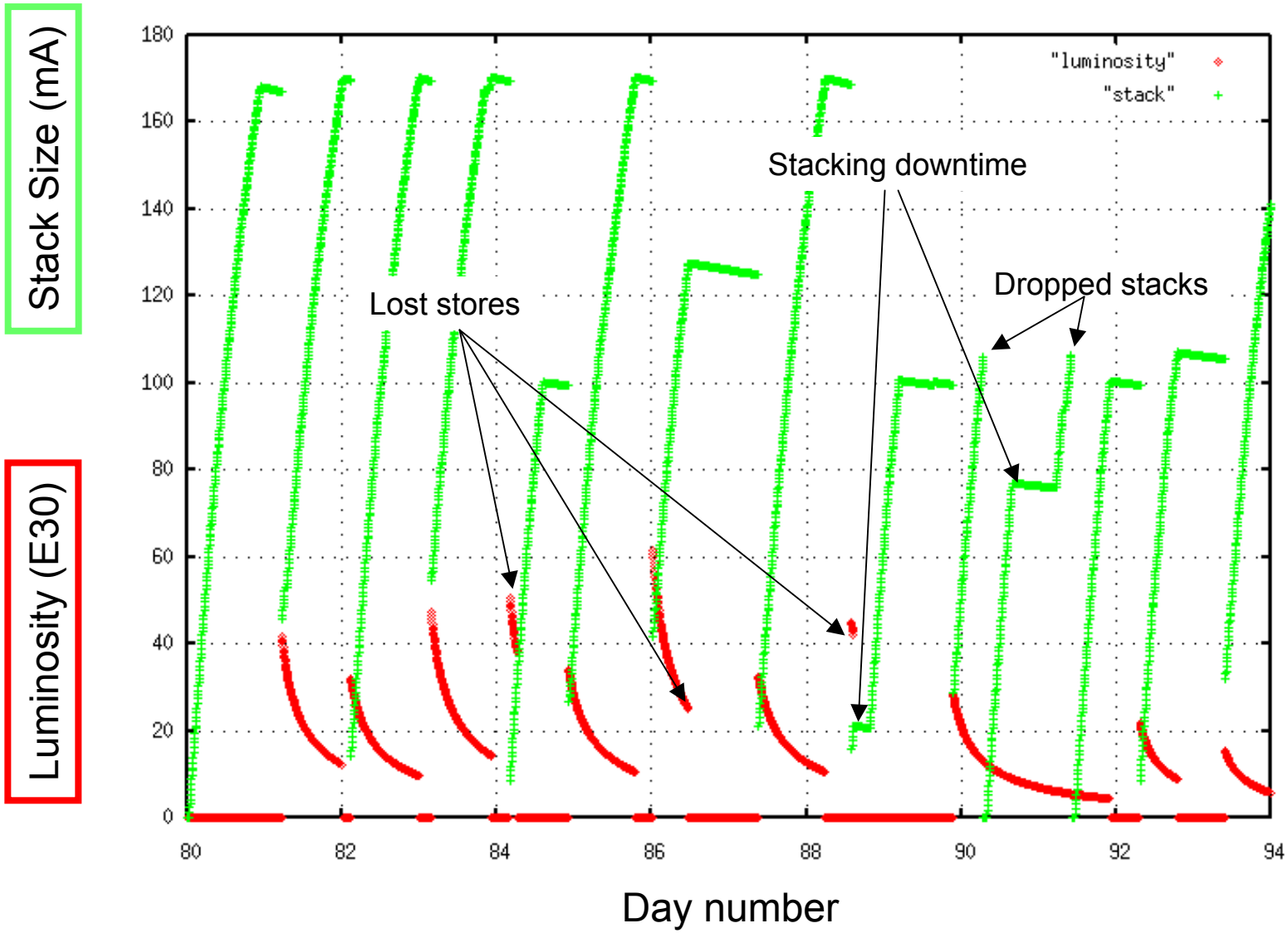
FY04 Study Strategy

- FY04 Parasitic Study Strategy
  - Recycler "Pbar Tax"
    - 25% of the Pbar stacking time line will go to Recycler commissioning
    - Uses of the tax: MI Access time, Proton events, Pbar transfers
  - Present 80% Stack size / 20% Time-line strategy
- FY04 Dedicated Study Strategy
  - A study period would begin only if the previous 14 days contained 140 hours of store time.
  - Study periods would occur twice a week.
  - Study periods will be short (8-12 hours)
  - There would be at least two stores between each study period.
  - Studies would be blocked according to themes.
  - At the end of the study block (or theme) a short write-up (TEV Note or Pbar Note) describing the results of the studies would be expected.
- Maintenance studies would occur at the discretion of the Run Coordinator.

Shot Strategy

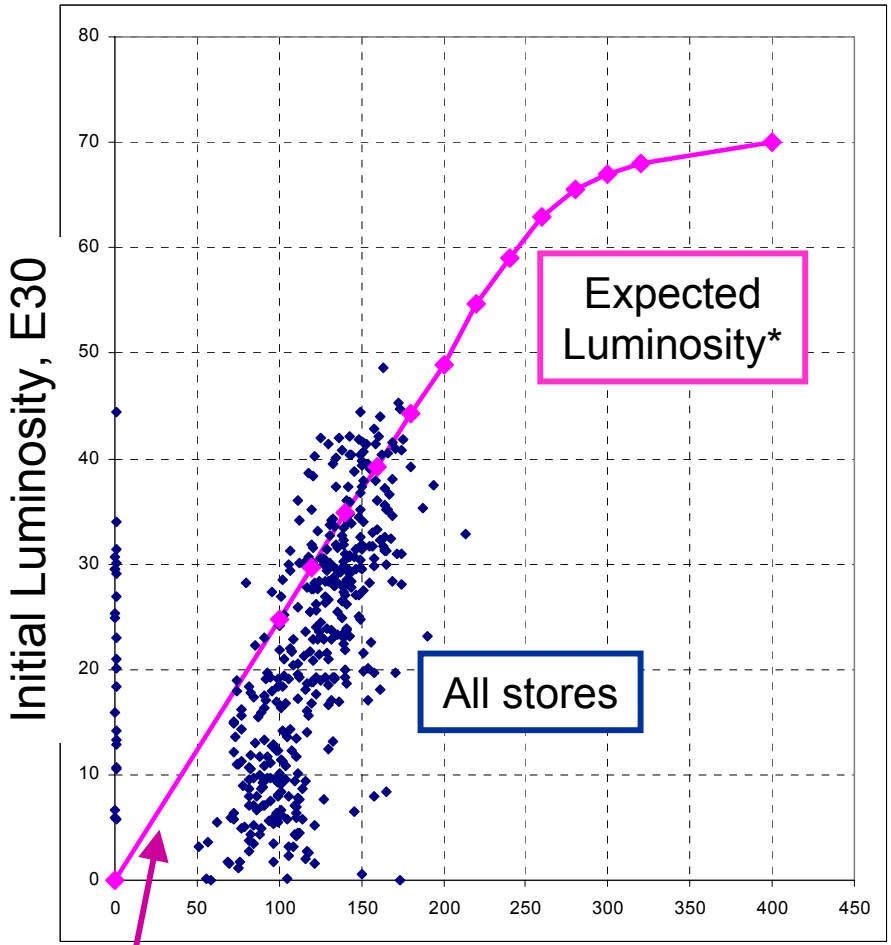
- What is the best strategy for ending a store?
  - How long should we run the stores?
  - What stack size should we shoot from
- What is the best strategy for recovering from TEV failure or a lost Pbar Stack?
  - What is the minimum stack we should shoot from.
- When is the best time to do studies?
- We are re-developing a Monte-Carlo model of the TEVATRON Complex
  - Will incorporate a realistic model of the TEVATRON based on realistic parameters obtained from SDA
  - Will model the inherent randomness of the Collider Complex
    - Downtime (based on SDA)
    - Variations on all realistic parameters (based on SDA)

Simulation of a Typical 2 Week Stacking Period



Algorithms for Ending a Store

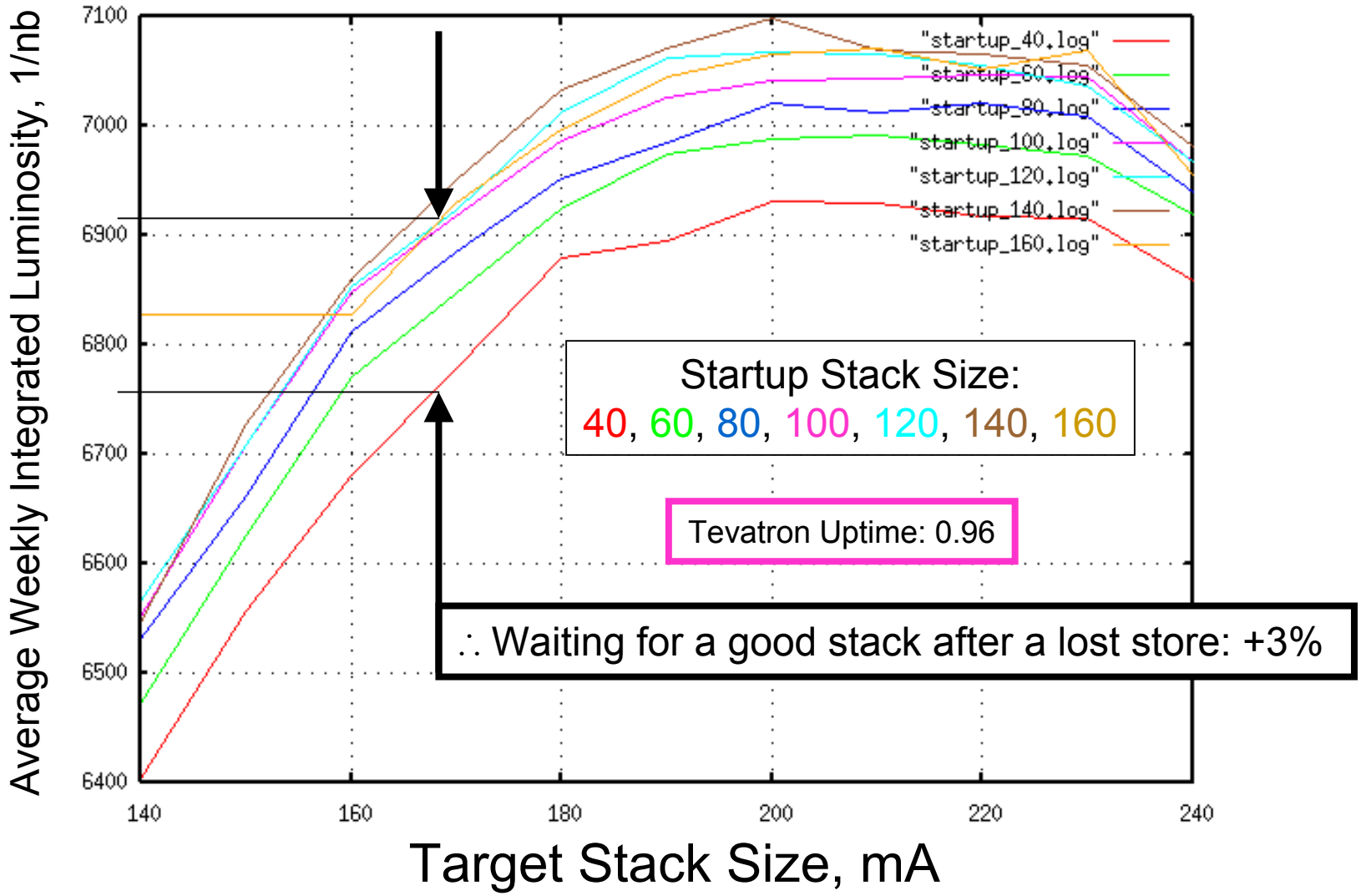
- Target Crossings
  - Stack Size
  - Store Duration
  - Integrated Luminosity
  - Minimum Instantaneous Luminosity
- Luminosity Potential
  - Comparison of "Expected" instantaneous luminosity and present instantaneous luminosity
    - When the ratio between the expected luminosity and the current luminosity exceed some constant, V.
    - When the difference exceeds constant, L.



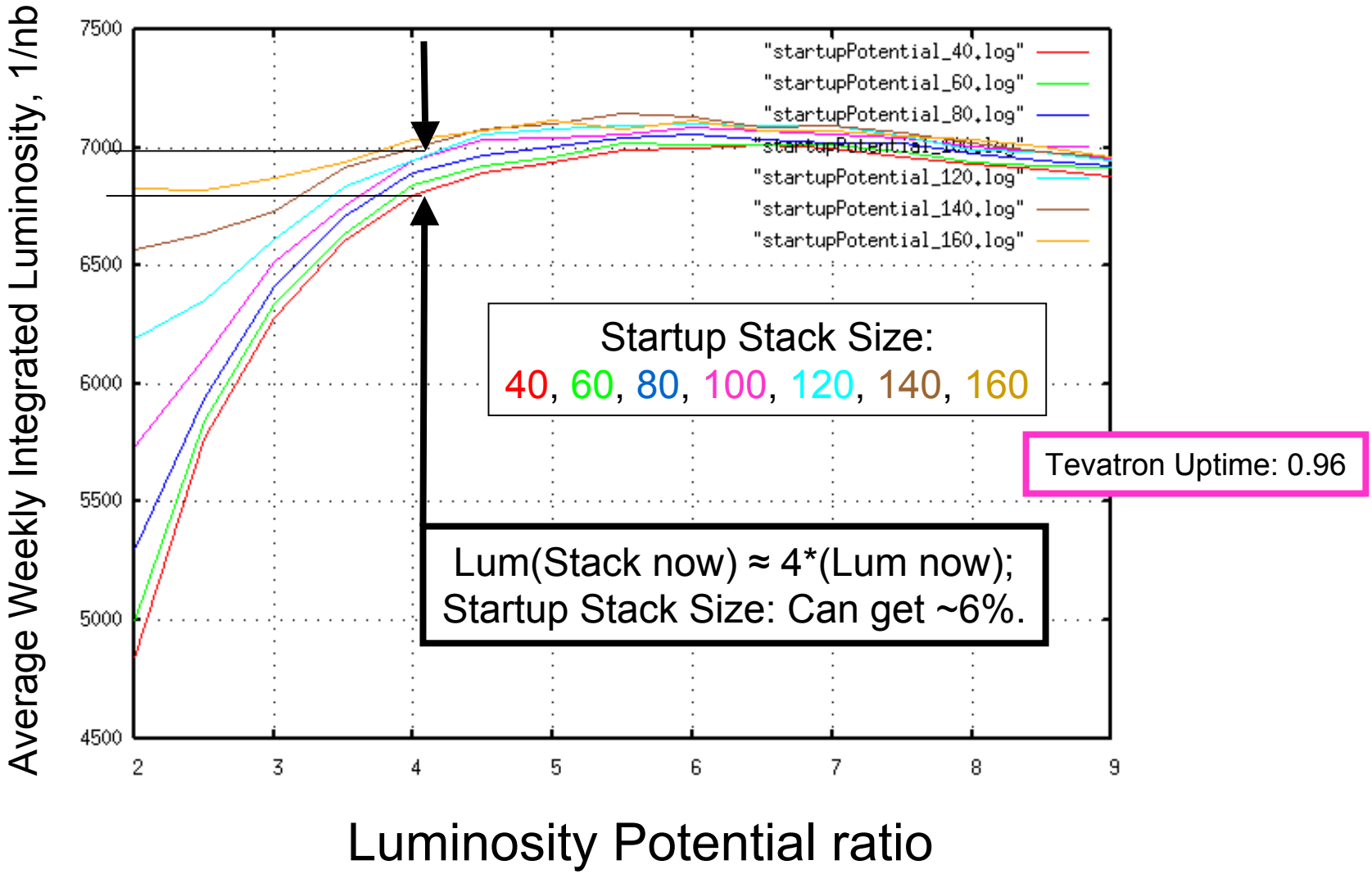
*Generated by the model; error bars (σ) ≈ 20%

Needs more confirmation from SDA

Target Stack Size and Recovery from TEV Failure

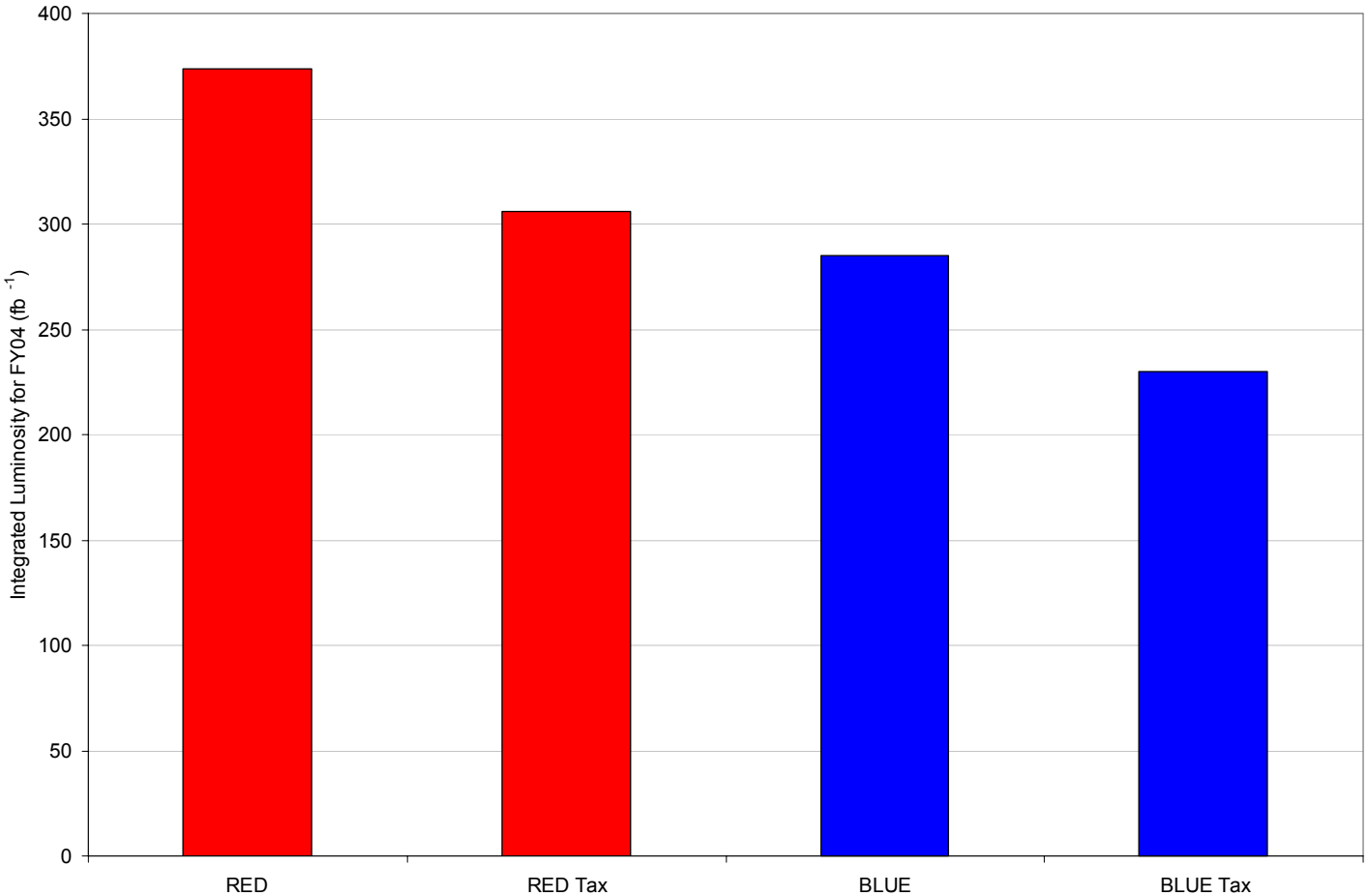


Example of Startup Stack Size and Luminosity Potential Ratio



FY04 Luminosity Parameters

FY04 Integrated Luminosity



Fiscal Year	RED	RED Tax	BLUE	BLUE Tax	
FY04	373	306	285	230	pb^{-1}

Luminosity Parameters

		Luminosity Parameters				
Phase	FY03	FY04	FY04	FY04	FY04	
Initial Luminosity	37.9	74.9	61.9	53.4	43.3	$x10^{30}cm^{-2}sec^{-1}$
Average Luminosity	20.7	44.4	36.8	30.5	24.7	$x10^{30}cm^{-2}sec^{-1}$
Integrated Luminosity per week	6.4	13.7	11.3	9.2	7.4	pb^{-1}
Integrated Luminosity per store	1.1	2.4	2.0	1.6	1.3	pb^{-1}
Number of stores per week	5.7	5.7	5.7	5.6	5.6	
Average Store Hours per Week	85	85	85	84	84	Hours
Store Length	15	15	15	15	15	Hours
Store Lifetime	11.0	13.0	13.0	12.0	12.0	Hours
HEP Up Time per Week	98	98	98	96	96	Hours
Good Week Ratio	1	1	1	1	1	
Shot Setup Time	2.2	2.2	2.2	2.2	2.2	Hours
	FY03	**RED**	**RED TAX**	**BLUE**	**BLUE Tax**	

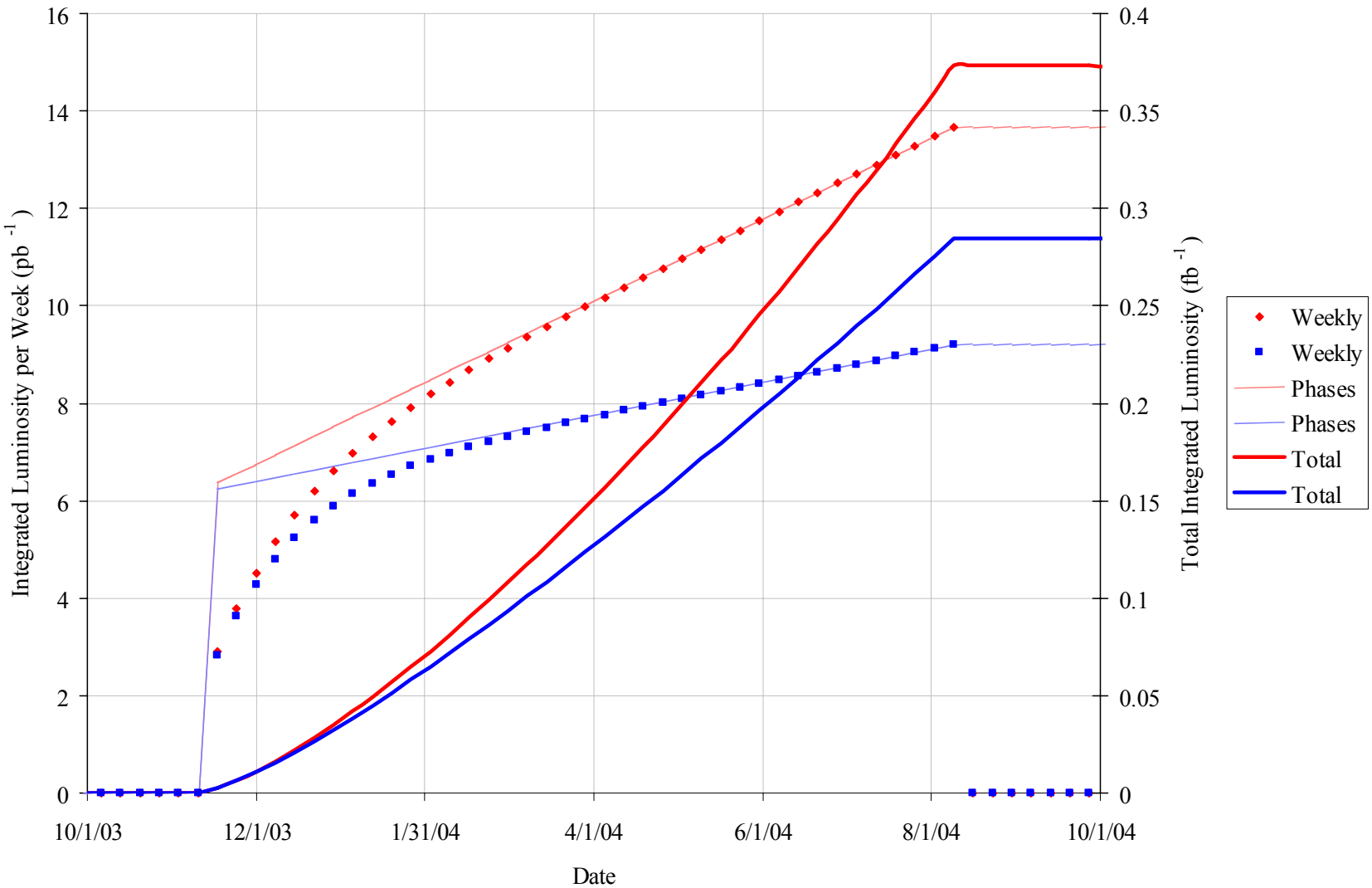
TEVATRON Parameters

		TEVATRON Parameters				
Phase	FY03	FY04	FY04	FY04	FY04	
Number of Protons per bunch	250	260	260	260	260	$x10^9$
Number of Pbars per bunch	24.9	37.6	31.1	30.3	24.5	$x10^9$
Proton Emittance	32	29	29	31	31	π-mm-mrad
Pbar Emittance	16	13	13	15	15	π-mm-mrad
σ_{proton}	0.525	0.500	0.500	0.500	0.500	meters
σ_{pbar}	0.525	0.500	0.500	0.500	0.500	meters
BetaIP	40	35	35	37	37	cm
Transfer Eff. To Low Beta	0.73	0.8	0.8	0.77	0.77	
Using SBD Calibration Back Calculated Emittances	FY03	RED	RED TAX	BLUE	BLUE Tax	

Antiproton Parameters

		Antiproton Parameters				
Phase	FY03	FY04	FY04	FY04	FY04	
Zero Stack Stacking Rate	11.3	18.0	18.0	13.7	13.7	$x10^{10}$/hour
Average Stacking Rate	8.2	11.3	9.3	9.4	7.6	$x10^{10}$/hour
Stack Size transferred	122.6	169.1	139.9	141.4	114.6	$x10^{10}$
Stack to Low Beta	89.5	135.3	111.9	108.9	88.2	$x10^{10}$
Pbar Production	15.0	17.0	17.0	16.0	16.0	$x10^{-6}$
Protons on Target	5	5	5	5	5	$x10^{12}$
Pbar cycle time	2.4	1.7	1.7	2.1	2.1	Secs.
Pbar up time fraction	1	1	0.75	1	0.75	
Initial Stack Size	15	15	15	15	15	$x10^{10}$
Stack Size at 1/2 Stacking Rate	150	150	150	150	150	$x10^{10}$
	FY03	**RED**	**RED TAX**	**BLUE**	**BLUE Tax**	

Integrated Luminosity per Week – no Pbar tax



Integrated Luminosity per Week – with Pbar tax